MPAS-Ocean Update

MPAS-Ocean Team

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- MPAS release 4.0
  - Gent-McWilliams Parameterization
  - KPP vertical mixing within CVMix
  - Multiple I/O streams: run-time specification of write frequency and variables

- In-Situ Analysis and Initial Conditions

- Spin-up of new standard meshes
  - Low-resolution (EC 60-30 km)
  - High-resolution (RRS 15-5 km)
  - Idealized Southern Ocean Configuration

- Residual-Mean prognostic framework

- In-Situ Lagrangian Particles

- CDG high-order advection scheme

- Land-ice/ocean coupling
**In-Situ Analysis**

**Problem:** Our ability to produce data is outstripping our ability to manipulate and analyze this data.

**Solution:** Analysis tools fully integrated into the model

- Analysis members:
  - Global, zonal, and regional statistics
  - Volumetric T/S census
  - Meridional heat transport
  - Eddy diagnostics and census (Woodring et al. 2015)
  - Lagrangian particles (Wolfram et al. JPO 2015)
  - Eliassen-Palm Flux Tensor

- Available in forward mode (in-situ) and analysis mode (post-processing)

- Each analysis member is a separate module, begun from a template.

- Easy for MPAS users to contribute analysis tools back to released code

- New multiple I/O streams: run-time specification of write frequency and variables.

Low Resolution Mesh: EC 60-30 km

- EC: requires Eddy Closure, i.e. GM is on.
- 234k horizontal cells: compare to POP 1 degree (86k cells)
- 100 vertical levels, z-star coordinate
- CORE-II six-hourly forcing underway
High Resolution Mesh: RRS 15-5 km

- RRS: Rossby Radius Scaling
- 5.8M horizontal cells, 100 levels. Compare to POP 0.1 degree (5.4M cells)
- Ocean-only spin-up underway

Grid cell size

Performance

Strong scaling of MPAS-Ocean, RRS.15-5km (5.8M cells, 60lev)

wolf: Intel Xeon, 2.6GHz
Southern Ocean-Enhanced Mesh

- Captures eddy dynamics of Southern ocean without eddy closure scheme.
- May include refined embayments for sub-ice shelf dynamics.
- Collaboration with NCAR (B. Large, SCIDAC) to analyze and remedy biases in Southern Ocean uptake.
- In planning stages

**Grid cell size**

- High-res Southern Ocean: 1.5 km
- Low-res Northern Hemisphere: 50-70 km
- Embayment: 6 km
Parameterizing eddies in a residual-mean prognostic framework


Conventional eddy param. with bolus velocity:

$$\mathbf{u}_* = - \frac{\partial}{\partial z} (A \mathbf{S})$$

Param. in residual-mean framework, using thickness-weighted average (TWA), as a force:

$$f \frac{\overline{\sigma' v'}}{\overline{\sigma}} = f \mathbf{u}_*$$

Planetary PV

$$f \overline{N^2}$$
An Idealized configuration of the Southern Ocean

- To investigate eddy-mean flow interaction with E-P flux tensor
- Lateral restoring leads to a $N^2(z)$ that produces a 1st Rossby radius of deformation of 12 km.
- Lateral restoring independent of longitude.
- Embayments/shelf for the creation and study of “AABW” creation and fate. Temperature restored to -1°C.
- Imposed wind stresses and heat fluxes over main channel.
- Provides stepping stone to simulations including static ice shelves and utilizing ~1 km resolution in embayments.
LIGHT: A tool for understanding mesoscale mixing

Lagrangian In-situ, Global, High-performance particle Tracking

- In-situ particle tracking with native spatial and temporal resolution
- High-performance (same number of particles as cells)
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- Scientific application: Diffusivity calculation
  - Cluster statistics in double-gyre basin
  - Potential density constrained (isopycnal)

Diffusivities estimated with LIGHT cluster of particles at four simulation resolutions, from eddy permitting to eddy resolving.

See poster OMWG-8 by Phillip Wolfram

see Wolfram et al. JPO, in press
High Order Tracer Advection

Characteristic Discontinuous Galerkin (CDG)

- New advection scheme for improved scaling with an increasing number of tracers and relaxed CFL
- Tracer field represented by a high order series of trial functions in each cell, \( k \),
  \[
  hq(\vec{x}, t) = \sum_j c^n_{k,j} \phi_j(\vec{x}, t)
  \]

Each face is traced back in time along characteristics and the polygon made by this face and its "pre-image" is integrated to determine the flux through the face.

See poster OMWG-3 by David Lee
Ocean / Land Ice Coupling

- Validating ice-shelf cavities in MPAS-O with ISOMIP (Ice Shelf-Ocean Model Intercomparison Project)
  - 20 vertical layers, nonlinear EOS, after 20 years

- New idealized test cases (MIPs) designed for a community effort:
  - **MISMIP+**: land ice only
  - **ISOMIP+**: ocean only with shelf cavities
  - **MISOMIP1**: coupled land ice-ocean

  - Work led by Xylar Asay-Davis
Overflow and Entrainment

- Study of vertical coordinate, resolution, and vertical viscosity
- Vertical grids ranging in thickness from 15 m to 120 m were tested.
- Vertical resolution of 60 m are sufficient in this configuration

MPAS-Ocean: Tasks for coming year

- Working towards ACME V1.0 freeze Nov 1
- Coupling and testing within ACME
- CORE-forced and fully coupled simulations on:
  - Low-resolution mesh (EC 60-30 km)
  - High-resolution mesh (RRS 15-5 km)
  - Southern Ocean enhanced mesh
- Evaluation with active MPAS-CICE
- Biogeochemistry column library within MPAS
- Land-ice/ocean coupling and physics: idealized to realistic
- Initial condition generation
- Additional in-situ analysis
### Multiple run modes

- **init mode**: Creation of initial conditions, both idealized and realistic
- **analysis mode**: Post-processing analysis, applied to restart files.
- All modes have access to MPAS infrastructure (mesh, i/o, operators)
- All modes fully parallelized and scale like the forward model.
- All code in same repository
- Brings init and analysis under design and peer-review standards


